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Numbers, Diversity, and Phenology of Spiders (Araneae) Overwintering in Cardboard Bands Placed in Pear and Apple Orchards of Central Washington

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ABSTRACT Cardboard bands were placed on pear and apple trees at each of three sites to act as overwintering shelters for spiders. Bands were placed on the trees in late August, at three heights on the tree. One-third of the bands was collected in January to determine what taxa of spiders overwintered in the shelters. The remaining bands at each site were collected and replaced at weekly intervals between late August and early December to monitor phenology of movement into the shelters. More than 2,900 spiders in 10 families were recovered from the winter-collected set of bands. Spiders were collected from all three sampling heights in the trees. The majority of spiders were juveniles, although adults of some Salticidae [especially *Pelegrina aeneola* (Curtis) and *Phanias* sp.] were fairly common. The dominant families were Philodromidae (primarily *Philodromus* spp.) and Salticidae (primarily *P. aeneola*), comprising 66 and 28%, respectively, of the total specimens. In the weekly collections, >5,600 bands were sampled during the study producing >6,000 spiders represented by 12 families and 30 identified genera. Dominant taxa in the weekly collected bands included *Philodromus cespitum* (Walckenaer), *P. aeneola, Xysticus* spp. (Thomisidae), *Sassacus papenhoei* Peckham and Peckham (Salticidae), *Phidippus* spp. (Salticidae), and *Anyphaena pacifica* Banks (Anyphaenidae). Of these taxa, *Xysticus* spp., *S. papenhoei*, and *A. pacifica* were very uncommon in the winter-collected bands, and we infer from these results that these spiders used the bands as temporary refuges only, and overwintered elsewhere. Data obtained from the weekly collected bands suggested that *Philodromus* spp., *Dictyna* spp., *P. aeneola*, and *Cheiracanthium mildei* L. Koch entered overwintering shelters during the interval between mid-October and mid- to late November. Pear and apple blocks at the same site were more similar in community composition than a common crop species at two different sites. More spiders were recovered from bands placed in the unmanaged and organically managed orchards than from apple and pear blocks that received insecticides during the growing season.

KEY WORDS Araneae, overwintering, species diversity, orchards

PEST CONTROL STRATEGIES in pear and apple orchards of the Pacific northwest are changing as growers substitute mating disruption for organophosphate insecticides to control codling moth, *Cydia pomonella* (L.). Associated with decreased use of insecticides in pheromone-treated orchards has been an increase in densities of nontarget arthropods, both pest and beneficial. Indeed, one of the major drawbacks associated with use of mating disruption is the increase in damage caused by insects that historically were controlled incidentally by sprays directed at codling moth (Westigard et al. 1986, Alway 1998, Gut and Brunner 1998). However, because mating disruption also results in substantial increases in densities of beneficial arthropods (Knight 1994, Knight et al. 1997, Gut and Brunner 1998), natural enemies are providing control of certain secondary pests, such as aphids, leafminers, and leafhoppers (C.O.C., unpublished data).

The importance of spiders in suppressing pests in agricultural systems seems often to be under-appreciated (Riechert and Lockley 1984, Riechert and Bishop 1990). However, studies show that pear and apple orchards often have both high densities and high diversities of spiders, particularly if insecticide use is reduced (Dondale 1958, McCaffrey and Horsburgh 1980, Madsen and Madsen 1982, Bogya and Mols 1996, Wisniewska and Prokopy 1997, Miliczky et al. 2000). Indeed, in certain organically managed apple orchards of the Pacific northwest, the number of spiders in the tree canopy (as estimated by beating trays) may exceed the sum total of all other natural enemies, including hymenopterous parasitoids (E.R.M. unpublished data). Moreover, due to their diversity of sizes, hunting strategies, and microhabitat preferences, it is likely that the spider assemblage in reduced-pesticide orchards preys upon a variety of pests (Chant 1956, Riechert and Lockley 1984, Bogya and Mols 1996, Marc and Canard 1997).

One largely unexplored question about orchards and spiders is whether the orchard tree is an important overwintering site. Densities and taxonomic composition of spiders in the orchard during the growing season are almost certainly a function of dispersal, as in other systems (Turnbull 1973, Bishop 1990, Bishop and Riechert 1990). Less well understood is whether spiders that are common in orchards during the growing season also overwintered there. Tree banding studies in Europe indicate that a diversity of spiders may overwinter in orchards (Bogya et al. 1999). Similar studies using tree bands or other types of overwintering shelters have been done in pecan, peach, and pear orchards in the United States, and have shown that spiders do overwinter in orchards (Tamaki and Halfhill 1968, Fye 1985, Mizell and Schiffhauer 1987). However, the studies conducted in this country provided no information about what taxa overwintered in the bands; therefore, to fully understand community composition in the orchard during the growing season we need information about taxonomic composition of spiders overwintering in the orchard.

In this study, we banded pear and apple trees in central Washington orchards to address four objectives. First, we determined what types and numbers of spiders overwinter on trees in orchards. Second, we used bands to determine when (in autumn) certain taxa begin moving into overwintering shelters. Third, by sampling adjacent apple and pear orchards, we determined whether these two crops had similar communities of spiders. Finally, we placed the shelters at three heights in the tree and determined whether band location on the tree affected densities of overwintering spiders.

Materials and Methods

Study Sites. Three study sites were monitored. At all three sites both pear and apple blocks were sampled. The Parker site, located just southeast of Yakima, WA, comprises a 15- to 20 yr-old block of 'Bartlett' pear (3.2 ha), and a 2.8-ha block of 15-yr-old 'Red Chief' and 'Silver Spur' apples. Mating disruption was used in both blocks to control codling moth. A cover spray of oil + chlorpyrifos was used in the apple block in late spring before the study. The pear block received an oil spray in March, followed by early-May and late June applications of abamectin. A 2 m wide strip beneath the trees in both blocks was kept weed-free by spring applications of herbicide. The second site, at Moxee, is an experimental orchard maintained by USDA-ARS located 15 km east of Yakima. A 1.2-ha block of 15-yr-old Bartlett pear trees and a 2-ha block of 10-yr-old 'Golden Delicious' apple trees were monitored. Arthropod pests were not controlled. Herbicide was used in early summer to control weeds in a 2-m strip beneath the trees. The third site, Tieton, is located 20 km west of Yakima. The apple and pear blocks both have received organic certification. Applications of oil and lime-sulfur are used to supplement biological control of arthropod pests. The pear block consists of 2.2 ha of ≈15-yr-old 'Bosc' and Bartlett trees. The apple block comprises a 2.4-ha block of ≈15-yr-old 'Red Spur' trees. A 2 m wide strip beneath trees was kept weed-free by flaming the strip, a practice that was continued beyond the growing season and into the current study interval. Lime was deposited at the base of the apple trees in late fall.

Sampling. Bands composed of corrugated cardboard were used to provide overwintering shelters. The bands were 7.6 cm wide and long enough to completely encircle the trunk or limb of the tree. Corrugations were ≈4 by 5 mm. Corrugations of this size may have been too small to allow some larger spiders to colonize the bands. However, spiders that were collected using these bands were composed to a large extent of the same taxa that dominate collections made from the orchard tree canopy during the growing season (Miliczky et al. 2000); thus, any sample bias due to size of the corrugations was of minimal importance. We monitored three heights in the tree: band around trunk just above ground level; band around trunk just below crotch of tree (generally 0.1–0.3 m above lower band); and band 0.5–1 m above crotch of tree along largest limb. Bands were wrapped around the trunk or limb and the two ends were stapled together.

In late August 1999, 30 bands were placed at each of three heights in 30 trees at each orchard and in each crop (with one exception; see below), for a total of 90 bands per crop per site. Trees were selected randomly except that border rows were avoided. In each crop, one-third of the bands (i.e., 10 bands per height) was left in the orchard until January. Data from these bands provided information about what taxa of spiders overwinter in the orchard. The remaining two-thirds of the bands (20 trees) were collected and replaced at weekly intervals to monitor spider phenology. That is, by removing and replacing bands at weekly intervals, we were able to determine for several taxa when, in late summer and autumn, spiders moved into overwintering sites. Sample size at the Moxee site (pear block) for the overwintering study was 18 trees rather than 10 trees; a second, unrelated study was being done at this site employing similar banding methods, and we used data collected from those 18 trees in the current study. Sample size at the Moxee (pear block) site for the weekly collected bands was 20 trees, as at the other orchards.

For the phenology study, the 20 bands per height and crop at each site were collected at weekly intervals between late August and early December. On each collection date, a new band was placed in the same location as the original band. Bands removed from the trees were placed in large plastic bags, with the three heights kept separate. For statistical purposes (see below), the 20 trees in each plot were numbered, and the bands were marked with the appropriate tree number before being put in the bags; thus, we knew from what tree each band had originated. Bags filled with bands were taken to the laboratory and placed in a walk-in cooler until they were processed. Bands were in transit for up to 30 min between the field and the walk-in cooler, thus there may have been some movement by spiders among bands. The winter-collected bands were handled in the same manner as the weekly collected bands.

Table 1. Number of spiders from winter-collected bands at three heights in the tree and for two crops

Family	Species	Pear			Apple		
		Upper	Middle	Lower	Upper	Middle	Lower
		Moxee site					
Anyphaenidae	*Anyphaena pacifica* Banks	—	—	3	—	—	3
Araneidae	*Araneus* sp.	2	—	—	—	—	—
Clubionidae	*Cheiracanthium mildei* L. Koch	—	—	—	—	1	—
Dictynidae	*Dictyna* spp.[a]	1	9	42	—	4	26
Gnaphosidae	Unidentified	1	1	—	—	—	—
Philodromidae	*Philodromus cespitum* (Walckenaer)	217	632	765	40	173	109
	P. rufus Walckenaer	—	1	1	1	—	—
	Tibellus sp.	—	—	1	—	—	—
Salticidae	*Habronattus* sp.	—	1	2	—	—	5
	Pelegrina aeneola (Curtis)	25 (0,1)	56 (0,3)	58 (0,3)	8	45	62 (0,2)
	Phanias sp.[b]	1 (0,1)	2	1 (0,1)	—	2	1
	Phidippus spp.[c]	9	14	36	2	3	8
	Salticus sp.	—	—	1	1	—	—
	Sassacus papenhoei Peckham & Peckham	1	1	1	1	—	—
Theridiidae	*Theridion* sp.	1	—	—	—	—	—
Thomisidae	*Xysticus cunctator* Thorell	—	1	—	—	—	—
	Misumenops celer (Hentz)	—	2	—	—	—	—
Totals		258 (0,2)	720 (0,3)	911 (0,4)	53	228	214 (0,2)
		Tieton site					
Clubionidae	*Cheiracanthium mildei*	—	—	1	—	—	—
	Unidentified	—	—	—	—	—	1
Gnaphosidae	Unidentified	—	1	1	—	—	1
Linyphiidae	*Erigone* sp.	—	—	1 (0,1)	—	—	—
	Unidentified	—	—	1	—	—	—
Lycosidae	Unidentified	—	—	—	—	1	—
Philodromidae	*Philodromus californicus* Keyserling	—	—	—	4	2	—
	Philodromus sp.	—	—	—	4	1	1
Salticidae	*Pelegrina aeneola*	8 (0,1)	3 (0,1)	1	105 (0,6)	165 (0,11)	101 (0,5)
	Phanias sp.[b]	—	—	—	24 (4,4)	24 (10,4)	9 (2,4)
	Sassacus papenhoei	—	—	1	1	—	—
Theridiidae	*Theridion* sp.	—	—	—	—	1	—
Thomisidae	*Misumena vatia* (Clerck)	—	—	—	1	—	—
Totals		8 (0,1)	4 (0,1)	6 (0,1)	139 (4,10)	194 (10,15)	113 (2,9)
		Parker site					
Anyphaenidae	*Anyphaena pacifica*	—	—	1	—	—	—
Clubionidae	*Cheiracanthium mildei*	—	4	12	1	7	9
	Clubiona moesta Banks	—	—	—	1 (0,1)	—	—
Dictynidae	*Dictyna* spp.[a]	—	—	1	1	3	5
Gnaphosidae	*Micaria* sp.	—	—	1	—	—	—
	Zelotes sp.	—	—	—	—	1	1
Linyphiidae	Unidentified	—	—	2	—	—	—
Philodromidae	*Philodromus* sp.	—	—	—	—	—	1
	Tibellus sp.	—	1	—	—	1	—
Salticidae	*Pelegrina aeneola*	2	1	2	—	1	2
	Phidippus sp.[c]	2	2	—	7	11	15
	Sassacus papenhoei	—	—	3	—	—	—
	Salticus sp.	—	—	—	—	1	1
	Unidentified	—	—	1 (0,1)	—	—	—
Thomisidae	*Misumenops celer*	—	—	1	—	—	—
Totals		4	8	24 (0,1)	10 (0,1)	25	34

Numbers refer to summed counts of spiders for all bands, including spiders aspirated from bags containing bands. Values in parentheses indicate number of adults in the bands (M, F). Sample sizes are 10 bands per crop × height × site, except for Moxee pear in which sample size is 18 bands per height.

[a] Apparently mostly *Dictyna coloradensis* Chamberlin; may include some *D. borealis cavernosa* Jones.

[b] May be *Phanias watonus* (Chamberlin & Ivie).

[c] Apparently mostly *Phidippus audax* (Hentz); may include some *P. clarus* Keyserling and *P. johnsoni* (Peckham & Peckham).

In the laboratory, length of the band was first determined; band sizes differed due to variation among trees in size and age, and because limbs had a smaller circumference than trunks. After the band was measured, it was pulled apart and all spiders were aspirated. Specimens that had spun up on the cardboard between the band and the tree were also collected. Spiders were identified to species or genus when possible using available keys. For some juveniles, we could identify specimens to genus or family only. Representative samples of the more common specimens were reared to the adult stage to confirm some identifications (Miliczky et al. 2000). Adults were sexed. Spiders that were left in the bag after all bands had been processed were also aspirated and identified. Because these specimens could not be categorized according to the tree from which they originated, they were excluded from any of the formal statistical tests.

Data Analysis. Much of this study is descriptive and required no formal statistical tests. Densities of spiders were compared among heights using analysis of variance, incorporating tree as a blocking factor. Densities were expressed as numbers per band and as numbers per 100 cm^2 of band. Separate analyses were done for each orchard and crop. Similarity of spider communities among sites or between crops was described by calculating a distance index (Ludwig and Reynolds 1988, Miliczky et al. 2000):

$$\text{Relative absolute distance (RAD)} = \sum^{s}\left(\text{Absolute value}\left[\left(X_{ij}/\sum^{s}X_{ij}\right)-\left(X_{ik}/\sum^{s}X_{ik}\right)\right]\right),$$

where j and k refer to the two sites, X_{ij} is the abundance of the i^{th} taxon at site j, X_{ik} is the abundance of the same taxon at site k, and s is the total number of taxa. In this study, due to difficulties in classifying many juvenile specimens to the species' level, we calculated the index using abundances of the different spider genera. The index varies between 0 and 2, where 0 indicates that the two sites were identical and two indicates maximum dissimilarity.

Results

Spider Numbers and Taxa in Winter-Collected Bands. The 204 bands that were placed in the orchards in late August and then collected in January contained >2,900 spiders in 10 families (Table 1). Spiders occurred at all three heights in the trees (Table 1). The collections were dominated numerically by members of the Philodromidae and Salticidae, comprising 66 and 28%, respectively, of the 2,953 spiders collected (summing the three sites). Most of the spiders were juveniles. One species, *Philodromus cespitum* (Walckenaer), was particularly abundant at Moxee in both pear and apple blocks, constituting >81% of the total at this site. Densities of *P. cespitum* exceeded 40 per band at the lower sampling height in pear. All specimens of this species were juveniles (Table 1). *Pelegrina aeneola* (Curtis) was common at Moxee in both pear and apple (11% of Moxee sample), and at Tieton in the apple block (83% of the total; densities exceeded 10 per band at all three sampling heights; Table 1). Adults (females only) of this species were present in fairly large numbers (Table 1). A second salticid, *Phanias* sp., was also abundant at the Tieton site (averaging 1.9 per band; heights combined), and adults of both sexes were collected. Few spiders were collected in either crop at the Parker site (Table 1). *Cheiracanthium mildei* L. Koch (Clubionidae) and *Phidippus* spp. [apparently mostly *P. audax* (Hentz)] (Salticidae) were the most common taxa collected, comprising 31 and 35%, respectively, of the Parker sample.

Spider Numbers and Taxa in Weekly Collected Bands. For the phenology study, we processed 5,760 bands collected over a 15- to 17-wk interval (Figs. 1–3). Spiders moved into bands well into December with largest numbers entering bands tending to occur in late October to mid-November, coinciding approximately with leaf fall in the orchards (Figs. 1–3). Seasonal peaks in numbers varied between nine spiders per 20 bands (Parker apple; lower bands [Fig. 3]) to 162 spiders per 20 bands in pear at the Moxee site (middle bands; Fig. 1). Bands at all three heights contained spiders, with the two lower bands tending to have higher numbers than bands at the upper height (Table 2). Adjusting counts for band size resulted in reduced height effects, although again bands at the lower levels tended often to have higher numbers than bands at the upper height (Table 2).

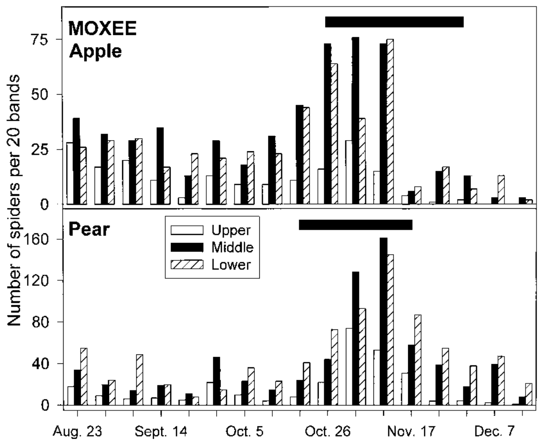

Fig. 1. Weekly total number of spiders per 20 bands (including spiders aspirated from the bags containing the bands) at three heights in pear and apple trees; Moxee site. Horizontal bars indicate timing of leaf fall. Each bar based on 20 bands. Scale of y-axis differs between panels.

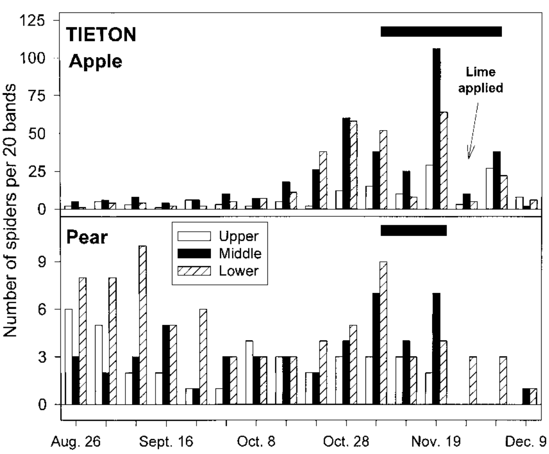

Fig. 2. Weekly total number of spiders per 20 bands (including spiders aspirated from the bags containing the bands) at three heights in pear and apple trees; Tieton site. Horizontal bars indicate timing of leaf fall. Each bar based upon 20 bands. Scale of y-axis differs between panels.

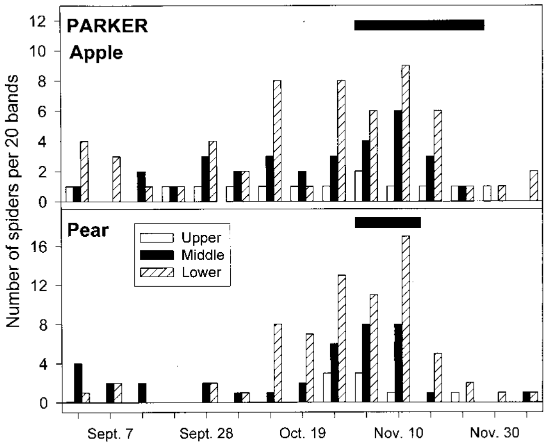

Fig. 3. Weekly total number of spiders per 20 bands (including spiders aspirated from the bags containing the bands) at three heights in pear and apple trees; Parker site. Horizontal bars indicate timing of leaf fall. Each bar based on 20 bands. Scale of y-axis differs between panels.

More than 6,000 spiders representing 12 families and 30 identified genera were recovered from the 5,760 weekly collected bands (Table 3). Samples were dominated by Philodromidae at Moxee (74% of Moxee sample), and by Salticidae at Tieton (79% of Tieton sample). The Parker site had considerably lower counts than the other two sites, but had absolutely and comparatively more Clubionidae (*Cheiracanthium mildei*) than the other two sites. The majority of spiders at all three sites were juveniles, although adults of *Pelegrina aeneola* (females) and *Phanias* sp. (males and females) were again common.

We ranked spider genera by abundance in the weekly collected bands and compared these rankings with those for the overwintering bands (Table 4). In four genera, abundance in the overwintering bands was substantially lower than what might have been expected based on numbers in the weekly collected bands: *Anyphaena, Xysticus, Sassacus,* and *Ebo* (Table 4). This result suggests that these genera used the bands as temporary refuges only, and overwintered elsewhere.

Community Similarity Among Sites and Between Crops. A dissimilarity index was calculated to compare spider communities between pairs of sampling sites (Table 5). The measures are based on the numbers of spider genera in common at the paired sites, not on numbers of species. Lower values indicate increasing similarity. Pear and apple blocks at the same site (Table 5) were invariably more similar in community composition than blocks at different sites, even when the comparisons between sites were for a common crop type. This pattern occurred in both the winter samples and the weekly collections (Table 5).

Phenological Patterns for Major Taxa. By collecting bands on a weekly basis, we were able to make inferences about when in autumn certain taxa began entering overwintering quarters (Figs. 4–6). Some care must be taken in interpreting these figures, because certain taxa seem to have used the bands as temporary refuges only and not as overwintering shelter. Thus, *Sassacus papenhoei* Peckham & Peckham (Salticidae), *Anyphaena pacifica* (Banks) (Anyphaenidae), and *Xysticus* spp. (Thomisidae) were common in bands in August and September, but were uncommon in bands collected later in autumn (Figs. 4–6). Moreover, few specimens of these taxa were recovered in the overwintering bands (Table 4).

Taxa that were common in both the weekly collected and winter-collected bands included *Philodromus cespitum, P. californicus* Keyserling, *Phidippus* spp., *Pelegrina aeneola, Dictyna* spp. (apparently mostly *D. coloradensis* Chamberlin), and *Phanias* sp. Phenology curves suggest that *P. aeneola* began entering overwintering sites in late October and early November, and completed most of this movement by late November (Figs. 4–5). *Philodromus cespitum* at Moxee showed a similar pattern. *Dictyna* spp. at Moxee began showing up in bands in large numbers during late September, and had completed this activity by mid-November (Fig. 4). At Tieton, *Philodromus* spp. (mostly *P. californicus*) moved into bands very late (Fig. 5), to the extent that the Tieton population of *P. californicus* was ≈1 mo later in moving into bands than the congeneric *P. cespitum* at Moxee (Fig. 4). *Phanias* sp. at Tieton showed peak movement in late October (Fig. 5). At the Parker site, counts for all but two taxa were too low to indicate phenology (Fig. 6). Despite the low numbers (see Table 4 for sample sizes), the curves suggest that both *Cheiracanthium mildei* and *Phidippus* spp. moved into overwintering quarters during a burst of activity in late October (Fig. 6). The phenology curve for *Phidippus* spp. at Parker was

Table 2. Mean number of spiders (±SEM) at each height per band or per 100 cm^2 of band

Tree	Per band				Per 100 cm^2 of band			
	Upper	Middle	Lower	LSD	Upper	Middle	Lower	LSD
Moxee pear	14.00 (1.27)	35.05 (2.27)	41.50 (2.14)	4.22	6.85 (0.78)	9.48 (0.60)	10.72 (0.51)	1.34
Moxee apple	9.40 (0.96)	26.65 (1.96)	23.10 (2.36)	3.61	4.71 (0.46)	7.72 (0.60)	6.31 (0.67)	1.00
Tieton pear	1.85 (0.35)	2.40 (0.43)	3.90 (0.43)	1.09	0.77 (0.14)	0.44 (0.07)	0.78 (0.09)	0.33
Tieton apple	6.65 (0.87)	18.45 (1.96)	14.45 (1.81)	2.94	2.44 (0.26)	3.63 (0.26)	2.70 (0.21)	0.69
Parker pear	0.50 (0.14)	1.90 (0.27)	3.55 (0.55)	0.92	0.13 (0.04)	0.28 (0.04)	0.50 (0.07)	0.15
Parker apple	0.65 (0.18)	1.55 (0.35)	2.85 (0.39)	0.84	0.34 (0.10)	0.42 (0.13)	0.67 (0.13)	0.31

Numbers are season-long totals, excluding spiders aspirated from the bags containing the bands. Number of collection dates (see Figs. 1–3): Moxee (17), Tieton (16), Parker (15). Number of bands per height = 20. LSD for height means.

Table 3. Total spiders from weekly collected bands per 20 trees from three sites and in two crops (heights combined)

Family	Species	Moxee site		Tieton site		Parker site	
		Pear	Apple	Pear	Apple	Pear	Apple
Anyphaenidae	*Anyphaena pacifica* Banks	35	132	14	32	4	7
Araneidae	*Araneus* spp.	2	1	—	—	—	1 (0,1)
	Unidentified	—	1	—	—	—	—
Clubionidae	*Cheiracanthium mildei* L. Koch	—	1	—	1	19	15
	Clubiona kastoni Gertsch	—	—	—	—	1 (0,1)	—
	Clubiona sp.	—	—	—	—	—	1 (0,1)
	Phrurotimpus borealis (Emerton)	—	2	1	—	1	—
	Unidentified	—	—	—	—	1	2
Dictynidae	*Dictyna* spp.[a]	86	110	—	2	2	12 (1,0)
	Unidentified	—	2	—	—	—	—
Gnaphosidae	*Drassylus lamprus* (Chamberlin)	—	—	—	—	—	1
	Haplodrassus eunis Chamberlin	—	—	1	—	—	—
	Micaria spp.[b]	1	—	—	—	1 (1,0)	3
	Sergiolus sp.	1	—	1	1	—	—
	Zelotes spp.[c]	3	—	6 (1,1)	3	3	2
	Unidentified	10	18	6	—	2	4
Linyphiidae	*Erigone* spp.	1	1	2	2 (1,1)	6 (6,0)	—
	Meioneta fillmorana (Chamberlin)	—	—	1 (0,1)	1 (0,1)	2 (0,2)	—
	Spirembolus mundus Chamberlin & Ivie	—	1	6 (4,2)	1	—	—
	Unidentified	13 (2,0)	25 (2,2)	49 (10,12)	26 (5,3)	46 (1,1)	5 (1,0)
Mimetidae	*Mimetus* sp.	—	1	—	—	—	—
Philodromidae	*Ebo* spp.[d]	16	25	1	—	1	3
	Philodromus cespitum (Walckenaer)	2,677	770	1	3	4	3
	P. californicus Keyserling	—	—	1	71	—	—
	P. rufus Walckenaer	—	1	—	—	—	—
	Philodromus sp.	—	—	2	9	—	—
	Tibellus spp.	4	2	—	—	—	1
Salticidae	*Habronattus* sp.	6	—	—	—	—	2
	Metaphidippus vitis (Cockerell)	—	—	—	—	1	—
	Pelegrina aeneola (Curtis)	53	119	66 (0,4)	817 (0,53)	3	2
	Phanias sp.[e]	1	6 (0,1)	3	126 (30,32)	1	—
	Phidippus spp.[f]	102	71	19	14	16	28
	Salticus spp.	4	—	—	—	—	4
	Sassacus papenhoei Peckham & Peckham	70 (0,1)	129 (0,1)	1	6 (0,1)	5	14
	Unidentified	2	9	—	6	3	2
Theridiidae	*Theridion* sp.	—	1	1	—	—	—
	Unidentified	—	2	1	—	1	1
Thomisidae	*Coriarachne* sp.	—	2	1	1	—	—
	Misumenops celer (Hentz)	—	—	—	1	1	1
	Xysticus spp.[g]	124 (1,0)	81	12	15 (0,1)	6	7
Titanoecidae	*Titanoeca* sp.	1	1	—	—	—	—
Totals		3212 (3,1)	1514 (2,4)	196 (15,20)	1138 (36,92)	130 (8,4)	121 (2,2)

Numbers summed over sampling dates and heights. Counts include spiders aspirated from bags containing the bands. Values in parentheses show numbers of adults collected (M,F). Number of collection dates (see Figs. 1–3): Moxee (17), Tieton (16), Parker (15).

[a] Apparently mostly *Dictyna coloradensis* Chamberlin; may include some *D. borealis cavernosa* Jones.

[b] Includes *Micaria pulicaria* (Sundevall).

[c] Includes *Zelotes fratris* Chamberlin and *Z. puritanus* Chamberlin.

[d] Includes *Ebo pepinensis* Gertsch and *E. iviei* Sauer & Platnick.

[e] May be *Phanias watonus* (Chamberlin & Ivie).

[f] Apparently mostly *Phidippus audax* (Hentz); may include some *P. clarus* Keyserling and *P. johnsoni* (Peckham & Peckham).

[g] Includes *Xysticus cunctator* Thorell and *X. montanensis* Keyserling.

delayed compared with the curve for this genus at Moxee (compare Figs. 4 and 6: *Phidippus*). It is not clear why the curves differed.

Phenology curves for a given spider taxon tended to be very similar on apple and pear (compare filled and open symbols in Figs. 4–6).

Discussion

Spiders are often among the most abundant natural enemies in orchards if insecticide use is curtailed (Madsen and Madsen 1982, Miliczky et al. 2000). Densities of spiders in the tree canopy for temperate area orchards (in the absence of insecticides) appear often to follow a fairly typical seasonal pattern. Counts are generally low in spring, increase to a small peak in late spring and to a larger peak in summer, and then decline during autumn as spiders enter overwintering quarters (Dondale 1958, Olszak et al. 1992, Miliczky et al. 2000). The summer increase in counts is probably a function of both immigration and reproduction. It is not clear, however, whether reproduction in orchards is done mostly by migrants or by spiders that overwintered in the orchard. To begin to address this question requires information about overwintering, including a determination of what taxa overwinter in orchards.

Cardboard bands or other overwintering shelters have been used in orchards to monitor overwintering

Table 4. Total specimens collected for 10 most common genera in weekly collected bands and corresponding numbers in winter-collected bands

Pear			Apple		
Spider genus	Weekly bands	Overwintering bands	Spider genus	Weekly bands	Overwintering bands
			Moxee		
Philodromus	2,677	1,616	*Philodromus*	771	323
Xysticus	124	1	*Anyphaena*	132	3
Phidippus	102	59	*Sassacus*	129	1
Dictyna	86	52	*Pelegrina*	119	115
Sassacus	70	3	*Dictyna*	110	30
Pelegrina	53	139	*Xysticus*	81	0
Anyphaena	35	3	*Phidippus*	71	13
Ebo	16	0	*Ebo*	25	0
Habronattus	6	3	*Phanias*	6	3
Tibellus	4	1	*Tibellus*	2	0
			Tieton		
Pelegrina	66	12	*Pelegrina*	817	371
Phidippus	19	0	*Phanias*	126	57
Anyphaena	14	0	*Philodromus*	83	12
Xysticus	12	0	*Anyphaena*	32	0
Spirembolus	6	0	*Xysticus*	15	0
Zelotes	6	0	*Phidippus*	14	0
Philodromus	4	0	*Sassacus*	6	1
Phanias	3	0	*Zelotes*	3	0
Erigone	2	1	*Erigone*	2	0
Ebo	1	0	*Dictyna*	2	0
			Parker		
Cheiracanthium	19	16	*Phidippus*	28	33
Phidippus	16	4	*Cheiracanthium*	15	17
Xysticus	6	0	*Sassacus*	14	0
Erigone	6	0	*Dictyna*	12	9
Sassacus	5	3	*Xysticus*	7	0
Philodromus	4	0	*Anyphaena*	7	0
Anyphaena	4	1	*Salticus*	4	2
Pelegrina	3	5	*Philodromus*	3	1
Zelotes	3	0	*Ebo*	3	0
Dictyna	2	1	*Micaria*	3	0

by natural enemies, including spiders (Tamaki and Halfhill 1968, Fye 1985, Bogya et al. 1999). These studies indicate that spiders are common inhabitants of the overwintering fauna in orchards. Furthermore, the community may be quite diverse. Bogya et al. (1999) used cardboard bands to collect overwintering spiders in orchards of Hungary, and recovered 46 species belonging to 14 families and 32 genera. The most abundant species in the bands were members of the Clubionidae (*Clubiona, Cheiracanthium*), Philodromidae (*Philodromus*), and Thomisidae (*Misumenops*).

Table 5. Similarity of spider communities between paired sites for weekly collected bands (below diagonal) and winter-collected bands (above diagonal)

Tree	Moxee pear	Moxee apple	Tieton pear	Tieton apple	Parker Pear	Parker apple
Moxee pear		0.43[a]	1.85	1.79	1.73	1.76
Moxee apple	0.63[a]		1.52	1.46	1.57	1.70
Tieton pear	1.72	1.34		0.50[a]	1.46	1.79
Tieton apple	1.72	1.55	0.82[a]		1.70	1.88
Parker pear	1.59	1.28	1.14	1.65		1.08[a]
Parker apple	1.63	1.20	1.31	1.77	0.67[a]	

Lower values indicate increasing similarity.
[a] Similarity index for apple and pear blocks at the same site.

The investigation by Bogya et al. (1999) is one of the few studies that provides taxonomic information about spiders that overwinter in pear and apple orchards. Results reported in the current study for central Washington orchards indicate, as with the Bogya et al. (1999) study, that a taxonomic variety of spiders overwintered in the cardboard shelters. The overwintering community was dominated by Philodromidae (mostly *Philodromus cespitum*), Salticidae (mostly *Pelegrina aeneola*), and Dictynidae (*Dictyna* spp.), although scattered individuals of other families were also present. The abundance of Philodromidae and Salticidae in the bands is not unexpected, because these two families are often very abundant in orchards during the growing season (Legner and Oatman 1964, McCaffrey and Horsburgh 1980, Wisniewska and Prokopy 1997, Bogya et al. 1999, Miliczky et al. 2000). *Philodromus cespitum,* in particular, appears to be a very common spider in orchards (Wisniewska and Prokopy 1997, Bogya et al. 1999, Miliczky et al. 2000). Members of Philodromidae, Dictynidae, Theridiidae, and Thomisidae have been shown to overwinter in orchards in bark crevices or under bark flakes of older trees (Putman 1967a, 1967b; Bogya et al. 1999), and representatives of all four families were recovered in the bands (Table 1).

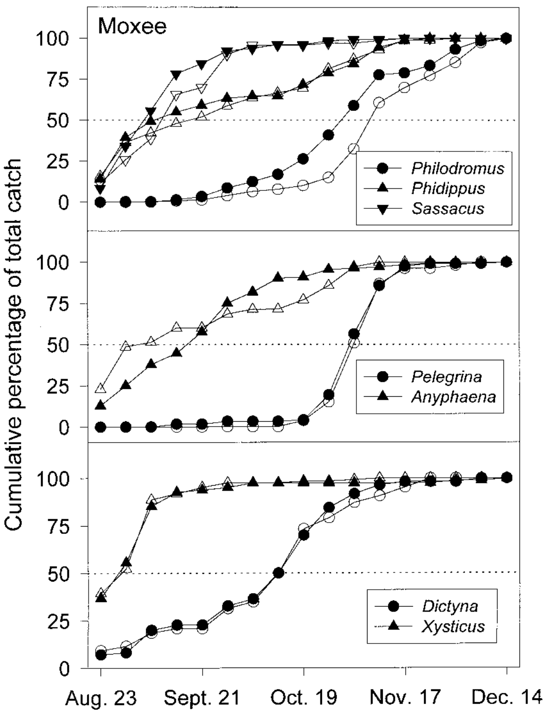

Fig. 4. Cumulative percentage of spiders collected in weekly-sampled bands for seven common genera at the Moxee site. Heights combined. Each point based upon 60 bands (20 per height). Apple, filled symbols; pear, open symbols. See Tables 3 and 4 for numbers of spiders on which percentages are based.

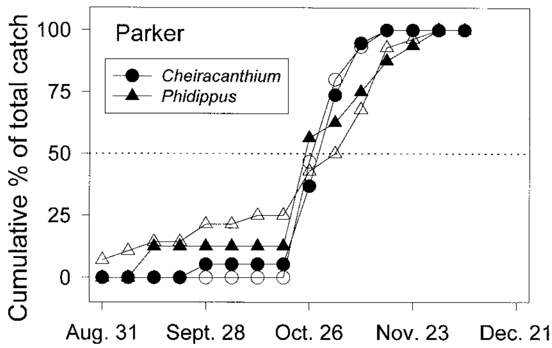

Fig. 6. Cumulative percentage of spiders collected in weekly-sampled bands for two genera at the Parker site. Heights combined. Each point based on 60 bands (20 per height). Apple, filled symbols; pear, open symbols. See Tables 3 and 4 for numbers of spiders upon which percentages are based.

The majority of specimens in the winter-collected bands were juveniles (Table 1). This was not unexpected, because most temperate zone spiders appear to overwinter as immatures in a mix of instars, reproducing in spring and summer (Schaefer 1987). Some adults were collected, mostly in the Salticidae (Table 1). Fairly large numbers of adult *Pelegrina aeneola* were noted in both the weekly collected bands (Table 3) and the winter-collected bands (Table 1). All adults of this species were females. Adult males of *P. aeneola* are rarely seen in the study area except in spring and early summer (E.R.M., unpublished data); sub-adult males of this species were very abundant in the cardboard bands (unpublished data). Adults of *Phanias* sp. were also collected in the cardboard bands (Tables 1 and 3). In this case, both sexes were present.

Bands at all three heights in the tree were colonized by spiders, which indicates that spiders will overwinter even well up in the tree canopy (Table 1). Duffey (1969) monitored seasonal movement of Clubionidae on oak trees by banding trees at different heights, and suggested that the method is useful to monitor movement by spiders down the tree in preparation for overwintering. He suggested that spiders, as they searched for overwintering quarters, moved down the tree from the canopy and often entered the first suitable overwintering site encountered rather than moving further down. This behavior might explain why several species in the current study were common in bands placed at the higher level in the tree. The only taxon in this study that showed any height preferences was *Dictyna* spp., which was collected primarily in the lower bands (Table 1). This same taxon was also abundant in the lower bands for the weekly collections (unpublished data).

Community composition was more similar between crop types (pear versus apple) at the same site than within crop types at different sites (Table 5). Given the generalized feeding habits of spiders, this result was not unexpected. Philodromidae dominated at the Moxee site in both crops, whereas Salticidae dominated at the Tieton site (Tables 1 and 3). Linyphiidae and Clubionidae were the most common families noted in the Parker samples (Tables 1 and 3). Site differences in community composition may have been due to geographical location, type of surrounding habitat (which included native habitat at Moxee versus

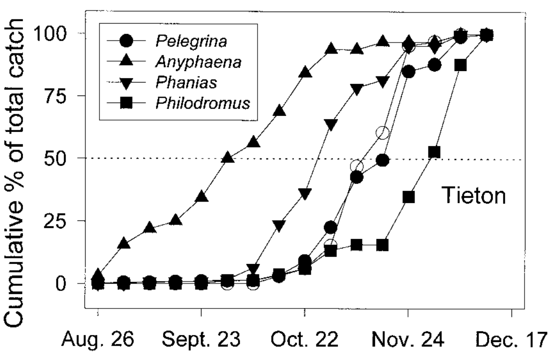

Fig. 5. Cumulative percentage of spiders collected in weekly-sampled bands for four common genera at the Tieton site. Heights combined. Each point based on 60 bands (20 per height). Apple, filled symbols; pear, open symbols. Too few specimens of *Anyphaena, Phanias,* and *Philodromus* were collected from pear to present curves. See Tables 3 and 4 for numbers of spiders upon which percentages are based.

orchard at Parker), or the type of pest-control program. Numbers of spiders recovered in the bands were largest at the unmanaged orchard (Moxee), followed by the organically managed apple orchard (Tieton). Considerably fewer spiders were collected in bands placed at the Parker orchard; this site, unlike the other two sites, received applications of insecticides. These results are consistent with other studies showing that unmanaged or organically managed orchards support considerably higher numbers of spiders than orchards receiving insecticides (Miliczky et al. 2000). One striking difference in spider numbers was noted between the organic pear and apple blocks at Tieton (Fig. 2). These blocks are within 30 m of one another, yet the bands placed in the apple block had counts of spiders that were nearly 10-fold higher than counts occurring in bands that were placed in the pear block. The difference was due to the high numbers of Salticidae in bands placed in the apple block, particularly in numbers of *Pelegrina aeneola* (Table 3). It is not clear why the two blocks should have differed to this extent.

Finally, the weekly collections of bands allow inferences to be made about the timing of movement into overwintering quarters for certain taxa (Figs. 4–6). Some care must be taken in interpreting these figures, because several taxa appeared to use the bands only as temporary refuges and not for overwintering, and other taxa may have used the bands for both temporary refuge in late summer and for shelter during winter. Taxa that were common in the weekly collected bands but were uncommon in the winter-bands included *Anyphaena pacifica, Sassacus papenhoei, Xysticus* spp., and *Ebo* spp. (Table 4). These spiders apparently used the bands for temporary refuge only, during August and September (Figs. 4–5). Spiders that were common both in weekly collected and winter-collected bands included *Philodromus cespitum, P. californicus, Phidippus* spp. (apparently mostly *P. audax*), *Dictyna* spp., *Pelegrina aeneola, Phanias* sp., and, to a lesser extent, *Cheiracanthium mildei.* These taxa showed peak counts in weekly collected bands occurring between mid-October and late November. One species, *Philodromus californicus* at the Tieton site, showed peak colonization of bands well into late November (Fig. 5). Many fruit growers in the Pacific northwest apply postharvest sprays of oil, sulfur, and insecticides against certain soft-bodied pest species (mites, psyllids, and scale). Results reported here suggest that several species of spiders would still be active in the orchard canopy at the time that these applications are made, with the result that densities of spiders overwintering in the orchard could be negatively affected.

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